**PATENT APPLICATION**
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# SYSTEM, METHOD, AND APPARATUS FOR SHARING COMMON CAPACITY DIFFERENT SCHEMES FOR RESTORING TELECOMMUNICATIONS NETWORKS


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## BACKGROUND

The present invention relates to communications networks and more specifically to failure response in communications networks.

Failures in communication networks, such as a fiber cut, require rapid response to prevent data loss and network slowdown. Optical Carrier (OC) links, such as OC-12, OC-48, and OC-192 carry high speed data across communications networks. As many as 160 OC Links can be compressed onto a fiber by a Dense Wavelength Division Multiplexer (DWDM), resulting in data transfer speeds as high as 1.6 trillion bits per second (Tbps). The high rate of data transfer requires efficient solutions to problems in transmission, such as breaks or equipment failure.

Accordingly, the data traffic is rerouted via an alternate path when a failure occurs. The data traffic can either be routed to another router or another DWDM. Routing traffic to another router can take between a few seconds and several minutes. Given the speed of the data traffic, rerouting to another router is not practical. Furthermore, even though rerouting to different DWDM is achieved at reasonable speeds (50 ms), data traffic cannot be rerouted when the cut occurs between the router and the DWDM.

To respond to failures between the router and the DWDM, additional links and routers are used. For example, a router may include a working port for transferring data and a protection port. Alternately, a router may be associated with a backup router for transferring data when the router fails. Optical Cross-Connect Systems (OXCs), include a Spare Physical Layer and a Spare Service Layer to be used during network failures. If a failure occurs between two OXCs, one OXC detects the failure and transmits the data using the Spare Physical Layer. If a failure occurs between the router and the OXC, the router detects the failure and the data is transmitted using either the protection port or the backup router. The protection port or backup router is connected by the OXC to the Spare Service Layer.

The extra capacity allows for fast restoration of the fiber optic network, but would result in very high costs due to adding the protection port and the Spare Physical Layer and the Spare Service Layer. For example, the costs of allocating additional resources is estimated to exceed $10 billion. Accordingly, what is needed is a system and method for restoring network failures quickly with minimal costs.

## SUMMARY

A system and method are disclosed for responding to a failure in a communications system. The failure is detected by a router and the router transmits data using the protection port. The router then sends a signal to the optical cross-connect system which indicates the failure and causes the optical cross-connect to connection the protection port to the working port. Thus, the costs can be mitigated by transmitting low priority data from the protection port/backup router via the Spare Service Layer, and preempting the low priority data during a failure.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a communications network for transferring data.

FIG. 2A is a block diagram of an optical cross-connect system (OXC) connected to a router.

FIG. 2B is a block diagram of an optical cross-connect system (OXC) connected to a router and a backup router.

FIG. 3A is a block diagram of the connections of the OXC where no failure is detected and a protection port is used.

FIG. 3B is a block diagram of the connections of the OXC where the OXC has detected a failure and a protection port is used.

FIG. 3C is a block diagram of the connections of the OXC where the router has detected a failure and a protection port is used.

FIG. 4 is a signal flow diagram describing the operation of the OXC and the router.

FIG. 5A is a block diagram of the connections of the OXC where no failure is detected and a backup router is used.

FIG. 5B is a block diagram of the connections of the OXC where the OXC has detected a failure and a backup router is used.

FIG. 5C is a block diagram of the connections of the OXC where the router has detected a failure and a backup router is used.

FIG. 6 is a signal flow diagram describing the operation of the OXC and the router.

FIG. 7A is a block diagram of the connections of the OXC, where no failure is detected and a backup router is connected to a second OXC.

FIG. 7B is a block diagram of the connections of the OXC, where a failure is detected and a backup router is connected to a second OXC.

FIG. 8 is a signal flow diagram describing the operation of the OXC and the router.

## DETAILED DESCRIPTION

Referring now to FIGURE 1, there is illustrated a block diagram of a communications network 100 for transferring data from a first terminal 105 to a second terminal 105. The optical network 100 comprises any number of routers 110, optical cross-connect systems (OXC) 115, and a Dense Wavelength Division Multiplexers (DWDM) 120. The routers 110 serve as gateways to the optical network 100 for any number of terminals 105. Information is transferred from terminals 105 to the router 110 in the form of packets. In addition to data, packets includes other information, such as the address of the destination terminal (destination address). The router 110 creates or maintains a table of the available routes and their conditions and uses this information along with distance and cost algorithms to determine the best route for a given packet.

The routers 110 are connected to OXCs 115 by any number of Optical Carrier (OC) links 117, such as OC-12, OC-48, and OC-192 links. OXCs 115 are also connected together via the OC links 117 to form a network and establish connection paths between the routers 110. Each OXC 115 receives any number of OC links 117 and connects

incoming lines to outgoing lines to establish connection paths from the first router 110 to a second router 110.

The OCXs 115 are interconnected by any number of the OC links 117 that are received at the DWDM 120 and compressed onto a single fiber 125. The signals on the fiber 125 are then decompressed by a second DWDM 120 that places the signals onto the OC links 117. As of present date, a single DWDM can combine the signals from 160 OC links onto a single fiber 125. Where each OC link is an OC-192, the fiber 125 transmits at rates as high as 1.6 Tbps.

Because of the huge amount of data carried, effective and speedy response to failures is essential. Accordingly, the data traffic is routed via an alternate path during a failure. The data traffic can either be routed to another router 110 or another DWDM 120 as discussed below.

Referring now to FIGURE 2A, the router 110 connected to the OXC 115. The router 110 includes a working port 205 and a protection port 210. The OXC 115 is connected to the DWDM 120 via OXC working ports 215, a spare physical layer 220, and a spare service layer 225. The working ports 205 and 215 are used to transmit data from and to the router 110. If a failure occurs between the OXC 115 and the DWDM 120, in Fig. 1, then the OXC 115 detects the failure and connects the working port 205 to the Spare Physical Layer 210. If a failure occurs between the router 110 and the OXC 115, the router 110 detects the failure and uses the protection port 210 to transmit the data. The protection port 210 is connected by the OXC 115 to the Spare Service Layer 225.

Referring now to FIGURE 2B, there is illustrated a block diagram of a router 110A and a router 110B, both of which are connected to an OXC 115. The OXC 115 is connected to the DWDM 120, as shown in Fig. 1, via OXC working ports 215, Spare Physical Layer 220, and Spare Service layer 225. The primary router 110A is used to transmit data via the OXC working porter 215. If a failure occurs between the OXC 115 and DWDM 120, then the OXC 115 detects the failure and connects the primary router 110A to the Spare Physical Layer 220 via path 221. If a failure occurs between the routers 110 and the OXC 115, then the router 110A detects the failure and alerts the

router 110B. The router 110B is used to transmit the data and is connected by the OXC 115 to the Spare Service Layer 225 via path 226.

The extra capacity allows for fast restoration of the network 100. The costs can be mitigated by transmitting low priority data from the protection port 210 or router 110B via the Spare Service Layer 225 and preempting the low priority data during a failure as needed.

Referring now to Figs. 3A – 3C, there is illustrated a block diagram of an OXC 115 with a Spare Port 305 connectable to either the working port 205 or the protection port 210. Referring to FIGURE 3A, the connections of the OXC 115 are illustrated where no failure is detected. The working port 205 of the router 110 is connected to the working port 215 of OXC 115. The protection port 210 of the router 110 is connected to the spare port 305 of the OXC 115. The protection port 210/spare port 305 connection can be used to transmit lower priority data that can be preempted when a failure is detected.

Referring now to FIGURE 3B, the connections of the OXC 115 are illustrated where the OXC 115 has detected a failure between the OXC 115 and the DWDM 120. When the OXC 115 detects a failure, the working port 205 of the router 110 is connected to the spare port 305 of the OXC 115. Any data carried on the protection port 210/spare port 305 connection, prior to the failure, is preempted.

Referring now to FIGURE 3C, the connections of the OXC 115 are illustrated where the router 110 has detected a failure between the OXC 115 and the router 110. When the router 110 detects a failure, the protection port 210 is connected to the working port 215 of the OXC 115 and the protection port 210/working port 215 connection is used to transmit the data. Any data carried on the protection port 210/spare port 305 connection, prior to the failure, is preempted. When a failure occurs between the router 110 and the OXC 115, the failure is detected by the router 110. However, in order for the OXC 115 to connect protection port 210 to the working port 215 of the OXC 115 in response to the failure, a signal is sent from the router 110 to the OXC 115, alerting the OXC 115.

Referring now to FIGURE 4, there is signal flow diagram describing the operation of the router 110 and the OXC 115. At step 405, the router 110 detects a

failure between the router 110 and the OXC 115. At Step 420, the router 110 transmits data using the protection port 210 to the OXC 115. At step 410, the router 110 alerts the OXC 115 of the failure of the working port 205 and directs the OXC 115 to connect the protection port 210 to the working port 215 of the OXC 115. The OXC 115 responds by connecting the protection port 210 to the working port 215 of the OXC 115.

The signal transmitted at step 410 can either be transmitted in-band or out-of-band. For example, the router 110 and the OXC 115 can be associated with Internet Protocol (IP) addresses, and the router 110 can send a message to the IP address associated with the OXC 115. Alternatively, the signal transmitted at step 415 can be transmitted using an in-band Synchronous Optical Network (SONET) message.

Referring to FIGURE 5A, the connections of the OXC 115 are illustrated where no failure is detected. The router 110A is connected to the working port 215 of the OXC 115 and the router 110B is connected to the spare port 305. The router 110B/spare port 305 connection can be used to transmit lower priority data that can be preempted when a failure is detected.

Referring now to FIGURE 5B, the OXC 115 has detected a failure between the OXC 115 and the DWDM 120 connected to the working port 215. When the OXC 115 detects a failure, the router 110A is connected to the spare port 305. Any data carried on the router 110B/spare port 305 connection, prior to the failure, is preempted.

Referring now to FIGURE 5C, router 110B has detected a failure of the router 110A. When the router 110B detects failure of the router 110A, the router 110B is connected to the working port 215 of the OXC 115 and the router 110B/working port connection 215 is used to transmit the data. Any data carried that was carried on the router 110B/spare connection 305, prior to the failure, is preempted.

When a failure occurs with the router 110A, the failure is detected by the router 110B. However, in order for the OXC 115 to connect the router 110B to the working port 215 of the OXC 115 in response to the failure, a signal is sent from the router 110B to the OXC 115, indicating the same.

Referring now to FIGURE 6, there is signal flow diagram describing the operation of the router 110B and the OXC 115 relating to Figs. 5A – 5C. At step 605, the router 110B detects a failure of the router 110A. Detection of the failure by the router

110B can occur, for example, by means of a signal sent from the router 110A to the router 110B indicating the same. At step 610, the router 110B alerts the OXC 115 of the failure of the router 100A. At step 615 the router 110B directs the OXC 115 to connect the router 110B to the working port 215 of the OXC 115 and the OXC 115 responds by connecting the router 110B to the working port 215 of the OXC 115. At step 620, the router 110B transmits the data.

The signal transmitted during step 610 can either be transmitted in-band or out-of-band. For example, the router 110B and the OXC 115 can be associated with Internet Protocol (IP) addresses. The router 110B can send a message to the IP address associated with the OXC 115. Alternatively, the signal transmitted during step 610 can be transmitted using an in-band Synchronous Optical Network (SONET) message.

The foregoing describes cases where the router 110A and the router 110B are connected to the same OXC 115. It is noted that the backup router 110B can be connected to another OXC 115. Referring now to Figs. 7A and 7B, there are illustrated block diagrams of routers 110A connected to a OXC 115A and routers 110B connected to an OXC 110B connected to a OXC 115B.

Referring to FIGURE 7A, there is illustrated the case where no failure is detected. The router 110A is connected to the OXC 115A and transmits data from the working port 215A of the OXC 115A. The router 110B is connected to the OXC 115B. The OXC 115A and the OXC 115B are interconnected via any number of intervening OXCs, 115(l)....115(N).

Referring now to FIGURE 7B, there is illustrated the OXC connections where the router 110B has detected the failure of the router 110A. Data from the router 110B is received by the OXC 115B. A free channel is established between the OXC 115B, each intervening OXCs 115 (l)....115(N) and the OXC 115A. The data transmitted from the OXC 115B to the OXC 115A via the free channel established over the intervening OXCs 115(l)...115(N). The OXC 115A connects the free channel to the working port 215A of the 115A and transmits the data therefrom.

Referring now to FIGURE 8, there is illustrated a signal flow diagram describing the operation of the routers 110B, the OXCs 115(A), 115(B), 115(l)....115(N). At step 805, the router 110B detects the failure of the router 110A and at step 810 the data is

transmitted from the router 110B to the OXC 115B. The router 110B sends a message signal 815 to the OXC 115B indicating the detected failure and directing the OXC 115B to establish a free channel to the OXC 115A. At step 820, the OXC 115B determines the route to the OXC 115A and sends a message signal 825(l) to the next intervening OXC 115(l) along the determined route. Message signals 825(l)...825(N) are sent from each intervening OXC 115(l)...115(N) to the next intervening OXC until a connection is established with the OXC 115A. At step 835, the last intervening OXC 115(N) sends a message signal 830 to the OXC 115A directing the OXC 115A to connect the free channel to the working port 215A of the OXC 115A. The data is then transmitted from the router 110B via the free channel through the working port 215A of the OXC 115A.

Although preferred embodiments of the present inventions have been illustrated in the accompanying drawings and described, it will be understood that the inventions are not limited to the embodiments disclosed, but are capable of numerous rearrangements, modifications, substitutions, and equivalents thereof without departing from the spirit of the invention as set forth and defined by the scope of the following claims.